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Influence of In-Service Teacher Training on Their Opinions about IBSE

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Abstract

The new Polish science curriculum was launched in 2008 and is currently being implemented in upper secondary schools. The new general objectives of education, and students' key competences that should be developed during science classes were defined in this document. The presented competences are in line with those that might be developed by Inquiry Based Science Education (IBSE). IBSE is currently a popular instructional method in many countries and it is being strongly promoted by the European Union. Unfortunately, most of the European Union member countries don't have national strategies in place to support the teachers responsible for implementing IBSE. In the article, a programme of science teacher training course which outline the basics of IBSE techniques was introduced. These course have been developed for polish science teachers basing on the Teachers Education Programme developed within the ESTABLISH project. The effect of the training on the attitude of Polish teachers to IBSE and the impact of training on the perception of selected aspects of IBSE was studied. The research was based on a survey questionnaire conducted among participants of the course before and after the training. The results show current position and degree of implementation of IBSE in Polish schools and the positive and negative factors affecting introduction IBSE into school practice.

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1. Introduction

The results of PISA in 2006 and 2009 (OECD, 2006, 2009a, 2009b) demonstrated the relatively poor

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performance of students from European countries in the fields of mathematics and natural science subjects. On the basis of these results, the European Commission created reports (Eurydice, 2011) that indicated that none of the EU member countries has a detailed national strategy for supporting low achievers in these areas, despite the fact that in five countries (Bulgaria, Germany, Spain, France and Poland) programmes aimed at improving this poor performance were launched. Although much has been achieved in terms of upgrading mathematics and science curricula, support for the teachers responsible for implementing those changes is still insufficient.

A method of improving this situation may be the promotion of activating teaching methods, such as learning through scientific inquiry. In Poland, the care for introduction of new teaching methods is expressed inter alia by the appropriate provisions in the current core curriculum (Polish Core Curriculum, 2008):

“...The most important skills acquired by students during learning within the general education program at the 3rd and 4th stage of education are:

3) Scientific thinking – the ability to use scientific knowledge to identify and solve problems, together with the ability to draw conclusions based on empirical observations of nature and society...”

And further:

“...During classes, the student should have a chance to observe, study, inquiry, explore laws and relationships, and achieve the satisfaction and joy of independent learning. The scope of the curriculum provides many opportunities for working with students using the educational project method (especially the research one), chemical experiment or other activating methods, which enable them to acquire information from different sources and process it in different ways. Observation carried out by the student himself is the basis of experiencing, reasoning, analysis and generalisation of phenomena, hence the significant role of experimentation in the implementation of the above-mentioned content”.

In the comments and recommendations to the curriculum, the method of working with particular teaching content can be found assisted by educational requirements. Requirements are described with operational verbs. Described actions and skill are in line with the competences that are taught with IBSE - Inquiry Based Science Education. The strategy of learning through discovery/scientific inquiry can be defined as ‘...an intentional process of problem diagnosing, carrying out a critical analysis of experiments and searching for alternative solutions, planning research, testing hypotheses, searching for information, constructing models, discussions with colleagues and formulating coherent arguments’. (Linn, Davis, & Bell, 2004)

The IBSE strategy is closely related to the principles of constructivism, the theoretical basis of which is formed by the papers of Vygotski (1926), Piaget (1929; 1958) and Papert (1991). One of the constructivism theorems states that the student’s knowledge is a result of active operation that is; a construction formed by the learner (Schwab, 1962). It means that through observation, performing experiments and reasoning, students build their own mental models (Drechsler, 2007), develop knowledge and understanding of scientific ideas.

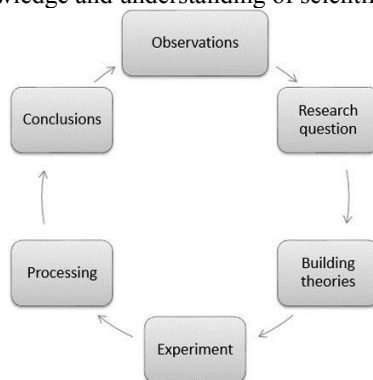


Fig. 1. A 6-stage cycle for inquiry investigations and modelling (NSES, 1996).

Scientific inquiry refers to investigation of problems in similar way in which scientists study the natural world and propose explanations based on the evidence derived from their work. The process of scientific inquiry can be presented as a cycle shown at Fig. 1. (NSES, 1996).

To implement these principles in practice, various models of science instructions can be used (Karplus, 1962; Martin, Sexton, and Gerlovich, 1999). At the Fig 2. the teaching model consists of a 5-step learning cycle is presented (ESTABLISH, 2010). The student should first develop an interest in the subject, then there should be a reference to the already possessed knowledge and then there is time for performing experiments and research after which the knowledge should be generalised and applied in different situations. The final stage is connected with the self-assessment of the student with reference to the acquired information. This cycle may illustrate the course of a lesson that is conducted only with the use of inquiry methods.

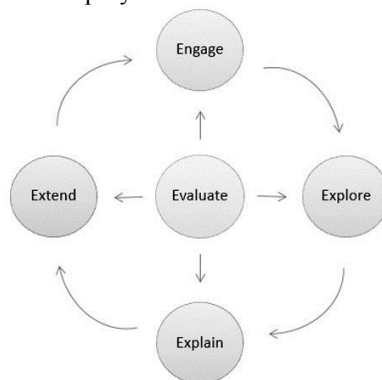


Fig. 2. Model of 5Es. Stages of learning (ESTABLISH, 2010).

The fact that students have to think, solve problems and investigate has been mentioned by many educators over the decades (Dewey, 1910; Bruner, 1960, 1962, 1966; Arends, 2004). Arends (2004) claims that the most general aim of the seeking strategy of teaching is to assist students in their learning to ask questions, searching for answers and solutions, in order to satisfy their own curiosity and to form their own theories and concepts. In classification of teaching methods developed by Okoń (1996), concept of multilateral teaching-learning, ‘learning through inquiry’ can be regarded as a group of methods connected with self-investigation in order to acquire knowledge. It must be remembered that the choice of method of conducting a particular lesson always belongs to the teacher, and the main issue is not whether to choose a lecture or discussion, but how to apply these techniques to assist rather than dominate the thinking of students. (Windschitl, 1999).

The popularisation and development of methods based on independent investigation carried out by the students themselves in order to gain knowledge has become one of the priorities in the 7th EU Framework Programme. Since 2007, the following projects have been implemented: Pathway, Pollen, INQUIRE, PROFILES, Primas, S-TEAM, Fibonacci, SAILS, and ESTABLISH (SCIENTIX, 2013) aimed at supporting the implementation of IBSE into school practices, development of teaching materials and reinforcement of the IBSE development.

The following article presents the science teacher training program in the area of IBSE methods. These courses were carried out within the ESTABLISH Project implemented in Poland. The article also contains the results of the survey that was conducted in order to discover whether and how the training affected teachers’ opinions about various aspects of IBSE. The paper is a continuation of the study published by Bernard & all (2013).

1.1. Description of the teacher training

Programme of the training was based on the Framework for Teacher Education Programme developed by ESTABLISH project (2011a). Presented below training was realized during 4 days long meeting (Summer or Winter school), and covered 33 hours of training. Understanding of the idea of teaching by inquiry was considered as the key issue of the training. It should be remembered that the educational process based on IBSE significantly departs from the process based on leading role of the teacher. This change is significant for people who had not participated in the courses conducted in this way before, and who have been using lecturing teaching methods in their school practice for many years. It is also important that teachers should be able to create such educational situations that will allow the student to develop the skills in line with the recommendations present in the core curriculum. During

the training, teachers had a chance to experience how the teaching process carried out in accordance with the principles of IBSE looks like. The theoretical part of the course was prepared in the form of lectures, described in the Appendix A.

Other elements of the training were focused on the autonomous work of the participants. During the seminars and laboratories, participants were cast in the role of a scientist studying a given problem area. They had to raise research questions, point out the hypothesis, plan and carry out the experiment, gather data and finally analyse, conclude and evaluate their own work. In the Appendix B and C, seminars and laboratory tasks were presented along with the objectives and a reference to the core curriculum.

In the ESTABLISH Project, special attention is paid to contact with industry. Therefore, the participants of the training were familiarized with the theoretical foundations of organizing scientific trips. This method of education can be successfully combined with an educational project method and IBSE (Maciejowska, Odrowąż, 2012)

2. The study

The aim of the study was to examine whether and how participation in the training influenced the teachers' opinions about various aspects of IBSE. Six areas that may affect the application of IBSE in schools were examined and analysed: 'The nature of IBSE', 'Teachers and IBSE', 'Students and IBSE', 'School curricula and IBSE' and 'Public attitudes to IBSE'.

2.1. The research group

The trainings for in-service teachers were realized in the form of a four day long meetings called the Summer or Winter School of the ESTABLISH Project. Two trainings covered with the study were attended by 87 in-service teachers from all over the country, details presented in Table 1.

Table 1. Number of training participants separated by subject thought and by level of education.

Level of education/ Subject thought*	No. of participants
Primary school	1
Lower secondary school	47
General upper secondary school	31
Vocational upper secondary school	6
Higher education	2
Chemistry teachers	80
Physics teachers	9
Biology teachers	10
Mathematics teachers	4
Computer Science teachers	2
Natural Science teachers	1

*Many of the participants were teaching more than one subject.





2.2. Research methodology

The research was based on a questionnaire survey consisted of 50 values that were presented in random order; the structure of the survey was the same before and after training. The survey was carried out among participants of training anonymously. From all responds two groups of 33 surveys were randomly-selected. One group covered answers before and second after training, results of both groups were compared.

The purpose of the surveys was to estimate which of the selected values differed before and after training. Each value may be classified into one of the six categories mentioned above. The differences were measured using a five-

point, bipolar scale of the following type: strongly disagree, disagree, not sure, agree, strongly agree. The responses were quantified using the following scale: -2 , -1 , 0 , $+1$, $+2$ and the overall results were presented graphically. The lengths of the bars of agreement and disagreement correspond to the overall level of agreement (positive) or disagreement (negative) were totalled independently. The resulting value was divided by the number of participants and multiplied by a scaling factor that could be adjusted to set the maximum size of bars in the presentation. The scaling factor was kept constant before and after training. Table 2 shows the maximum lengths of agreement and disagreement bars representing all answers of one type. The answer 'not sure' was not scored, and therefore, it did not influence the length of the agreement and disagreement bars.

Table 2. Structure of the survey questionnaire.

Tested value	Scale				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Numerical values assigned	-2	-1	0	1	2
Bars indicating the extent of agreement and disagreement					

2.3 Results

Tables 3-8 show the examined values associated with IBSE divided into the six categories. In the subsequent columns, there are answers of teachers before training, and the results obtained for the group after training.

Table 3. Results of the questionnaire describing the nature of IBSE.
























































The nature of IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
IBSE requires more thinking than traditional methods				
IBSE is more suitable for foundation level science courses				
IBSE is more suitable for higher level science courses				
IBSE favours the better students				
IBSE favours the weaker students				
IBSE requires more time than traditional methods				
IBSE requires discussion but there is insufficient time for this in school				
Inquiry methods require longer blocks of time than are not normally available in the school timetable				
Prescribed IBSE exercises defeat the purpose of IBSE				
Lab requirements are the same for IBSE and traditional methods				

Table 4. Results of the questionnaire describing the teachers' attitude to IBSE.

Teachers and IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
Teachers are generally convinced of the value of IBSE				
Teachers are generally aware of IBSE				
Inquiry methods are used in most other subjects				
Teachers prefer IBSE methods to traditional methods				
Teachers are not confident in using IBSE methods				
In general teachers have received adequate training in IBSE methods				
Teachers feel that they are not as much in control when students are engaged in inquiry				









IBSE requires more competence on the part of the teachers		
IBSE tasks are often interdisciplinary and can involve topics that are outside the teachers' comfort zone		
Teachers need deeper understanding if they are to facilitate students' engagement with challenging tasks		
There is insufficient cooperation between teachers of different subjects for IBSE		

Table 5. Results of the questionnaire describing the students' attitude to IBSE.

























Students and IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
Students are not interested in science				
Students prefer traditional methods				
Where IBSE is the norm students have more positive attitudes to science				
The topics in existing science curricula do not appeal to young people				
Students lack the ability to work independently				
Students lack the confidence to work without explicit instructions				
The laboratory is safer when students are engaged in IBSE				
Students are not confident in using equipment without explicit instructions				
The interdisciplinary nature of IBSE helps students to integrate their learning				
Students require a good foundation to benefit from IBSE				
Students in IBSE classes have a smaller scientific vocabulary				
Students find IBSE too difficult				

Table 6. Results of the questionnaire describing the inclusion of IBSE in existing school curricula.













School curricula and IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
Textbooks are generally suitable for IBSE				
Textbooks are too prescriptive for use in IBSE				
It is difficult to find suitable IBSE topics				
The curriculum is not appropriate for IBSE				
IBSE would require a different kind of curriculum				
It is possible to teach existing science curricula using inquiry methods				

Table 7. Results of the questionnaire describing the evaluation of students' working with IBSE.



































Assessment and IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
IBSE leads to better grades in examinations				
New forms of assessment are needed which do not disadvantage IBSE				
Examinations favour students of IBSE				
New forms of assessment are needed which favour IBSE				
It is difficult to compare students' achievement in IBSE because they are engaged in different tasks				
It is easier to assess students' progress using traditional methods				

Table 8. Results of the questionnaire describing the public attitude to IBSE.

Public attitude to IBSE	Before training		After training	
	Disagree	Agree	Disagree	Agree
Industry's requirements do not favour IBSE				
The system favours didactic methods				
School management supports the implementation of IBSE				
Teacher unions do not favour IBSE				
The school ethos does not favour IBSE				
Parents prefer traditional methods				

2.3. Results analysis

Despite the quantification of the results, the analysis is mainly qualitative. The following purpose of the study was adopted: identification of areas that were influenced by the training and determination of the direction of the change; the magnitude of change was not of major importance. Despite this, it can be stated in general that teachers became more confident in their answers after training; their opinions (both agreement and disagreement) are illustrated by longer bars.

While analysing the answers to questions regarding the character of the IBSE strategy, it can be seen that far less teachers think that IBSE favours better students than previously. Therefore, there is a chance that they will apply this strategy more widely in classes with average learning outcomes, which is the largest audience. After training, the teachers also put more emphasis on the importance of discussion as one of IBSE elements, but also on the lack of time associated with that. As a result of the participation of the teachers in the experimental classes and their familiarising (in practice) with the way of performing experiments in both a well-equipped laboratory and the usual seminar room, more of them agree that 'Prescribed IBSE exercises defeat the purpose of IBSE'. However, this opinion is still not dominant, despite the fact that teachers also realized that experiments performed according to IBSE rules can be carried out in the laboratory with the same equipment as is used for 'standard experiments'.

The results of the survey describing the views of the participants about the IBSE shows clearly that courses offered during the training changed their understanding of the IBSE concept, and particularly allowed them to make a distinction between the problem based methods and teaching through scientific inquiry. The participants of the training also had their opinions confirmed about the high demands on IBSE teachers in terms of not only the subject-specific competencies, but also the interdisciplinary and educational ones. The teachers decided that the knowledge about IBSE methods in Poland is still insufficient, and that the teachers community is not necessarily convinced about their high quality. The group of teachers which found that IBSE methods are used during most lessons is significant. There are also larger differences in opinions about the preparation of teachers for using IBSE.

The changes in teachers' opinions about the students' attitude to IBSE are surprising, as during the training, there were no courses allowing the direct observation of students. These changes might be a result of a more thorough understanding of the concept of 'learning through scientific inquiry'. Before the training, teachers were convinced that students do not prefer lecturing methods. After familiarizing them with methods of independent getting into knowledge, they concluded that students will not necessarily prefer such an approach to the classical methods. There is a clear difference between a student who performs or observes a demonstration of a classical school experiment and a student who carries out a research experiment.

The results of the survey show that the teachers had their opinions reinforced that IBSE has a positive influence on the students' attitude to the sciences and enables integration of the learning process. The teachers presented a more positive regard on the level of students skills required to independent laboratory practise. It can be a result of the simple measurement and research methods that were presented and that can be used by students in a simple classroom or at home.

After analysis of the section of the survey that refers to the description of the possible realization of the current textbooks and curricula with the use of IBSE it could be stated that the existing quite negative attitude was maintained. On the other hand, similarly to the previous study, the teachers find the possibilities of the realization of

the curricula with the use of IBSE but, at the same time, they have difficulties in finding topics that are suitable to be taught through the IBSE approach.

The issues relating to the assessment of students working with the use of the IBSE strategy indicated that the training reinforced the opinions of the teachers. The teachers notice the complexity of the problem of the assessment of students working through the IBSE. They are also aware of the fact that methods of working with students are dependent on the methods used in external examinations. Therefore, they consider that 'New forms of assessment are needed which favour IBSE'. Correlations between 'School curricula and IBSE' that were demonstrated during the training, probably increased the level of agreement with the statement that IBSE might have a positive impact on the examination results.

After training, the teachers opinion of the public attitude towards IBSE hasn't changed significantly. The agreement on the statements that 'The system favours didactic methods' and 'Parents prefer traditional methods' was slightly strengthened.

3. Conclusions

The fact that, after training, Polish teachers still have the opinion that curricula are not adjusted to IBSE is significant, and informs us that the introduction of IBSE into school practice will be a major challenge. On the other hand, the fact that the teachers, after training, reinforced their attitudes that existing curricula can be realized with the use of IBSE methods and that carrying out experiments according to the IBSE rules does not require more advanced equipment in school laboratories in comparison to the traditional methods, allows for an optimistic look at the future. Changes in attitudes are in this case less expensive than changes in external conditions. The stronger agreement that IBSE might have a positive influence on the examination results can be the result of a session on new forms of external examinations. The increase in the number of statements saying that the school system and parents are in favor of the traditional/lecturing methods gives teachers some kind of excuse for such rare application of the use of strategy that they found valuable but at the same time very demanding.

In general, it can be said that the almost week-long training carried out in the form of a workshop, with a significant number of experimental hours during which the teachers had a chance to take part in the process of scientific inquiry personally, led to an improvement in the understanding of the concept of IBSE among the training participants.

Acknowledgements

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Appendix A

Table 9. List of lectures at the training.

Title of the lecture	Aim
The teacher as an architect of the student's knowledge	Presentation of methodological foundations and evidence proving the effectiveness of the constructivist teaching model.
Types of activities within IBSE	Characterization of inquiry activities according to the students' independence and degree of teacher guidance.
The project method in the new Polish curriculum.	Discussion on the obligation to use the project method and the possibility to include IBSE i project group work.
The role of industry in chemistry education	Characterization of context based chemistry education and the role of the industrial context in the formation of knowledge and technology based society in 21 st century.
Methods of organizing a scientific trip	Formal regulations for the organization of an educational trip, including schools' and industrial companies' requirements. Based on (Maciejowska, 2007).

Appendix B

Table 10. List of seminars during the training.

Title of the seminar	Aim	Developed skills/ Formed attitudes	Reference to IBSE (ESTABLISH, 2011b)	Reference to the Polish Core Curriculum (2008)
<i>'Better to ask the way than to go astray'</i>	Stimulating student's interest in the subject. Stimulating student's curiosity Based on books and publications by O'Hare (2006, 2008), Feldman (2004) and Szymańska (2011). Teaching students to ask questions. A study of how to carry out a literature review in school.	Ability to formulate scientific questions and define problems Ability to find, select and critically analyze information.	Engage – The role of a teacher is to stimulate the interest and curiosity in the subject of the lesson or study, activation of the learning process and evaluation of knowledge already possessed by students.	Student asks questions regarding the phenomena occurring in nature, presents research attitude in understanding the world of nature by searching for answers to questions such as: "why?", "how is it?", "what happens when?"
<i>Scientific inquiry vs. problem based learning</i>	Presentation of the common elements of problem-based methods with the scientific-inquiry approach. Analysis of the constructivist cycle of scientific inquiry based on cycle by Llewellyn (2002).	Ability to identify research problems, and set up the agenda for the research. Ability to prepare descriptions, explanations, predictions and models on the basis of evidence Ability to use appropriate tools and techniques to gather, analyze and interpret various types of data. Ability to recognize and analyse alternative solutions and predictions	Students are able to find the core of the problem/question. Students apply their already-possessed knowledge in order to formulate working hypotheses. Students share, compare and develop their ideas.	Ability to use scientific knowledge to identify and solve problems, as well as to draw conclusions based on empirical observations of nature and society.
<i>Simple experiments planned and carried out according to the theory of IBSE</i>	Realisation of simple experiments beyond the school laboratory. Examples of investigations: a) Capacity of baby diapers b) Physical properties of polystyrene cups (foamed vs. non-foamed polystyrene) c) Solubility of sugar in water	Ability to use scientific knowledge to identify and solve problems Ability to plan and carry out simple experiments with the use of household materials and equipment Ability to determine the research problem and formulate hypotheses Ability to identify variables, construct charts, describe	Explore – during this type of activity, students ask questions, formulate hypotheses and work without direct instructions from the teacher – they collect evidence and data, write down and organize information, and exchange observations. The stage of planning the research: what actions will	Student observes and performs simple scientific experiments, analyses them and associated cause and effect. Student predicts the course of some phenomena and processes occurring in nature, explains the simple relationships between phenomena; carries out observations and

		relationships between variables, perform analysis of the results Ability to develop and apply mathematical thinking in solving problems resulting from everyday situations	be taken? How will the measurements be taken? What will be used for comparisons? The stage of interpretation of and discussion about data: which method was used to gather the data? Did all groups obtain the same results? Were the results the same in every repetition of the experiment? The stage of drawing conclusions and their refinement: Could the results obtained by different groups be compared? Was the experiment performed in a different way? Which method was the most effective? Why? Student asks open questions such as: Why do you think so? Have you got any evidence for that? Can you find any argument that contradicts your opinion? What do you know about this issue? What will be your answer to this question? What are the other arguments supporting your opinion?	experiments according to the instructions, writes down their results in various forms and explains them using appropriate terminology. Observation and experiment in chemistry; various possibilities of the application of chemical experiments (illustrative, research – introductory, research – problem discovery and research – problem verification) in the cognitive process.
<i>Art of discussion</i> <i>Art of debate</i>	Student learns the rules of constructive discussion. Student shares his ideas and discusses alternatives Student is ready for effective collaboration in a team and for making individual and group decisions.	Teamwork skills Ability to find, select and critically analyse information Ability to discuss and show respect for different opinions, formulate arguments and counterarguments Ability to participate in scientific discussion, behave properly during public appearances Ability to take feedback appropriately		Also other activating methods can be applied (e.g. expert compilation, active discussion, etc.).

Appendix C

Table 11. The list of laboratory classes during the training course.

Title of the laboratory class	Aim	Developed skills/ Formed attitudes	Reference to IBSE (ESTABLISH, 2011b)	Reference to the Polish Core Curriculum (2008)
Description of lab. for chemistry teachers: part I: <i>Chemistry of everyday life</i> . part II: <i>Polymers around us</i> .	Participants have the opportunity to define the research question, plan and carry out the investigation. Some examples of studied issues: What substance is used in commercially available filters for drinking water? Is the carbon filter able to remove ions of iron (III) from water? What determines the ability of a particular substance to penetrate through the membrane? What features should characterize the fabric used in sportswear production (e.g. for jogging), and what should be the characteristics	Ability to use scientific knowledge to identify and solve problems Ability to identify problems for investigation Ability to identify variables, describe relationships between variables and control variables Ability to formulate observations and draw conclusions, collect data, communicate with other researchers, explain, predict and make decisions Ability to develop and apply mathematical thinking in solving problems resulting from everyday situations Teamwork skills	Examination, investigation, and questioning the results of the experiments. Using the previous information to ask questions, propose solutions, make decisions and plan the experiments. Draws reasonable conclusions based on the evidence. Gives reasonable conclusions and solutions. Writes down observations, explanations and solutions. It is expected that students will plan and carry out the experiments by themselves, with only a little (or with no) help from the teacher. The research problem is given by	Student gains chemical knowledge through research – he observes, checks, verifies, concludes and generalises; indicates the relationships between the chemical composition, structure and properties of particular substances and their applications; uses chemical knowledge in everyday life in the context of health care and the protection of the environment. Student safely uses simple laboratory equipment and basic chemical reagents, he plans and performs simple chemical experiments. Student uses various sources

	of a fabric used for the production of waterproof clothing? Are all plastics 'light' and flammable? What elements or compounds are found in the products of the combustion of plastics?		the teacher, but the rest of the work is planned and carried out by students.	of information (his own observations, research, experiments, texts, maps, tables, photographs, films), takes measurements and uses instructions (verbal, textual and graphical), documents and presents the results of observations and experiments, takes advantage of information and communication technologies.
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